THE THIES PROCESS

OF

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BY

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THE pyrites containing gold resulting from the concentration of free milling gold-ores is usually treated by Plattner's process, which was introduced into Grass Valley, California, in 1858, by Mr. G. F. Deetken, and has been successfully practiced there from that time. Various modifications of it have, from time to time, been suggested. Mears proposed to use chlorine gas under pressure of 30 to 40 pounds to the square inch, made in a generator outside of the barrel and pumped into it or produced inside the barrel by the use of a great excess of chemicals; and while it was found that more gold was dissolved, the gain was more than compensated for by the expense of the machinery, the great cost of repairs, the trouble caused by the leakage of the gas and consequent loss of the chlorine and inconvenience to the men. Davis proposed to precipitate the gold with charcoal, but no special advantage resulted from it. The precipitation is slow, and the difficulty of burning such bulky material in a muffle and treating the ashes before melting into a bullion, caused its abandonment. Mr. A. Thies, by whose advice the process was introduced at the Phœnix and Haile mines in North Carolina, and the Bunker Hill mines in Amador City, California, having been in charge of the Mears process for more than four years, found that he could work without pressure-pumps just as well as with them, as all the pressure necessary for the solution of the gold, could be generated within the barrel just as well and much cheaper than by costly machinery, and after making a long series of experiments, leaving out of the Mears process all but the barrel, and having modified that so that there were no joints liable to leakage, in fact, so that there was nothing but the bare lead-lined iron cylinder left of it, perfected the process which is now known as the barrel process, but should be really known as the Thies process, which has been introduced at the Bunker Hill mine in Amador City, California,

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and at the Phœnix and Haile mines in North Carolina, where it has been working for several years very successfully.

Through the courtesy of Mr. N. W. Crocker, superintendent of the Bunker Hill mine, I had an opportunity to study this extremely interesting process at that mine. The details relating to the Haile and Phœnix mines have been forwarded to me by Mr. Thies. The Bunker Hill mine was located in 1852. It is situated 1½ miles north of Amador City. The vein dips at an angle of 75°, and varies from 3 to 25 feet in width. It has two inclined shafts, one of which is 800 feet long on the incline and 683 feet deep from the surface in a vertical line. The south shaft is 400 feet long on the incline and 345 feet vertically from the surface. The two shafts are 360 feet apart. The hanging is diorite and the foot slate. The ore is quartz and black slate, with 2 per cent. of sulphurets, and is worth $5 to $6 to the ton. It is crushed in Hendy's modification of the Blake's crusher, which is run by a 4-foot Knight's wheel under a pressure of 260 feet of water. The mill is run by a 6-foot Knight's wheel under a pressure of 270 feet. There is also a steam-engine to use in case of failure of the water. The mill has 40 stamps. The ore comes from the mine by a tramway, and is dumped on to grizzlies, and falls from there to a Hendy's rock-breaker, 9 inches by 16, which does all the crushing. The movement is transmitted by iron arms from one end of the breaker to the other. The stamps weigh 850 pounds, the stem is 350, the shoe 150, the boss 225. The tappit is of steel, and weighs 110. The stamps make 92 drops of 6½ inches, and each one crushes 2½ tons in twenty-four hours. The order of the drop is 1, 5, 2, 4, 3. The screens are No. 8, and are one-fourth of an inch angle slot, and last twenty days. The ore is amalgamated in the battery, and the splash-plate is arranged in such a way that the pulp falls on to an amalgamated plate 8 x 4 inches, inclined away from the mortar at an angle of about 45°, then drops to another one of the same size inclined towards it and then falls to the apron. This makes a fall from the screen to the first plate, and from the first to the second, and from the second to the sluice. The result of the constant impact is that little or no gold is found beyond these plates. The battery lip has two plates 8 inches long and 6 feet wide. The apron is 3 feet 6 inches long and 4 feet wide. It has a grade of 1½ inches to the foot. It ends in a single sluice, 14 inches wide and 12 feet long, with a single silver-plated copper plate. This ends in a pointed

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box for each sluice. 90 per cent. of the gold is found in the battery, 5 to 7 per cent. on the splash-boards and the rest on the plates. From the sluice the tails run on to Frues, which make 220 strokes. From the Frues the tails run on to duck sluices, of which there are 50, 22 inches wide and 16 feet long, exactly resembling the Strakes of the Keystone mill. The pulp from this Strake concentration is treated in pans with wooden shoes. The water used in the milling and on the concentrators is 8 miner's inches under a 4-inch head. The cost of milling is 60 cents. The number of men in the mill is 5 and in the mine 70. Both miners and mill-men are paid $2.75. The cost of water for milling is $1.60, and for power $18.40, per day.

The Bunker Hill and Phœnix works formerly used the Mears process, but were forced to abandon it because the cost of repairs was too great and it was found to be impossible to keep the chlorine from leaking, and the men refused to work when they were exposed to such corrosive fumes. There seems to be no doubt that the use of chlorine under very high pressure acts efficiently, and since its abandonment the tails are higher, but the difference is not enough to pay for the extra trouble and expense. This seems, for the most part, to be owing to the use of dry ore and dry gas, no water having been previously used, but the whole difference is not more than $2 per ton, which it seems impracticable to save on account of the difficulty of keeping the chlorine from leaking. All of the Mears process has therefore been abandoned, and as now conducted it does not bear much relation to the original process.

The concentrates at Bunker Hill are 2 per cent. of the ore, and contain a trace of arsenic, antimony and lead. Their average value is $60 to the ton. They are roasted with 1 per cent. of salt in a reverberatory furnace with a revolving hearth at the fire-place end. It is 40 feet long and 12 feet wide on the outside, with walls 18 inches thick. The stationary hearth is 7 feet wide, 18 feet long and 24 inches high, and has two working doors, one on each side of the furnace. They are 8x16 inches. At the end of the stationary hearth there is a drop of 6 to 7 inches. The ore then falls on to a horizontal revolving hearth 12 feet in diameter, with a discharge-hole in the centre. This part of the furnace is made of an iron shell lined with fire-brick. It is 24 inches high to the crown of the roof, and 18 inches to the spring of the arch. The working door is 3 feet above the floor of the

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roasting house. The bridge is 9 inches below the arch, and the grate-bars 18 inches below that, so that the fire-place and combustion-chamber together are 27 inches deep. This furnace is too small for any large output. The hearth revolves, by means of gear-wheels beneath it, at the rate of one turn per minute. The work consists in turning the concentrates over and bringing them from the centre to the circumference, and pushing them from the circumference to the centre. When finished, the charge is shoved from the centre, through the hollow axis of the hearth, into the cub below, and from there the roasted ore is removed by scrapers attached to the bottom of the pan and loaded into iron cars and carried in them to the cooling-floor. There are, in the furnace, three batches of 1100 pounds of ore. One is on the end of the hearth nearest the flue drying, the others being roasted. The charges are moved every eight hours. The same charge remains eight hours on the revolving hearth. To ascertain whether the roasting has been sufficiently prolonged to decompose all the sulphates, a small quantity of the hot charge is thrown into water, and a bright iron rod thrust into it. If there is any undecomposed sulphate, the rod will be acted on; if not, the charge is ready for the barrel. The capacity of the furnace is 2 tons in twenty-four hours. 0.25 per cent. of sulphur remains in the ore after roasting. It requires five-eighths of a cord of wood, at $6 per cord, to the ton. At the Haile mine, in North Carolina, a double reverberatory furnace is used; they have just erected a Spence furnace to roast the concentrates.

The cooling-floor is of brick, and is on the same level as the charging-hole of the chlorinating barrel. The charge is generally made hot, but not sufficiently so to be burning to the hand. It is weighed and charged in iron wagons. The barrel charging-floor is of wood, in the centre of which is a hole 2 feet in diameter, into which an iron hopper fits. The barrel is on the floor below, and has a man-hole 12 inches in diameter, which is turned up underneath this hopper. The barrel is of cast-iron or sometimes it is made of boiler plate, and is lined on the inside with lead, usually weighing 10 or 12 pounds to the square foot. All the joints are burned together when the lead is first put in. The lead used is one-quarter of an inch thick, and weighs 12 pounds to the square foot. After five years of use at the Phœnix mine, this lining shows no appreciable wear. The barrel is 4 feet in diameter outside and

40 inches inside, and 6 feet long outside and 54 inches inside. The heads are made of cast-iron with the trunnions cast on them, and are fitted to flanges on the body; these are fitted with tight and loose pulleys. The lining must be well put in and with great care. It is fastened at once by bolts to the outside, as it has been found very difficult, when repairs are required, to burn lead on which chlorine has acted. There were formerly in the barrel, on the bottom, partitions of lead 2 to 3 inches high, which make the charge rise and fall out as the barrel revolves, instead of simply rotating around on the bottom. This has been found to complicate the construction of the barrel unnecessarily and has been abandoned without any perceptible change in the work. When the chlorinating barrel is turned up, 135 to 140 gallons of water are introduced from a wooden barrel at the side of the hopper by a pipe. The exact quantity of water is ascertained by marks on the inside of the barrel, and as soon as empty it is filled again to be ready for the next charge. The water must be in sufficient quantity to allow the pulp to flow easily, but it must not be too thin. One ton of roasted sulphurets is now added through the funnel, it having been previously thoroughly mixed with 25 to 30 pounds of dry chloride of lime, which is the ordinary bleaching powder of commerce. This amount has been fixed on as the best, as it has been found that with a charge of 40 pounds no better results were obtained. When, as in some cases in North Carolina, the ore contains copper, more bleaching powder has to be used. The water is added first, because if the dry ore was added and then the water the barrel would be more than full, as the two would not mix, but the ore falls through the water, so that the barrel is filled up to 8 or 9 inches of the manhole. What remains on its sides is then washed off the funnel with a little water. Thirty pounds of sulphuric acid at 66° B. are added after the rest of the charge is made. An excess of acid must always be used, so as to be sure to convert all the lime which remains on the hopper, into sulphate, and the funnel washed free of acid, and then it is removed. In North Carolina the water is put in first, then the ore, and then the acid. The charge which answers best at the Phœnix mine, where the ore contains copper, is 40 of bleaching powder and 50 of commercial sulphuric acid. At the Haile mine, where the pyrites is free from copper, the charge is 10 pounds of bleaching powder and 15 pounds of acid.

Half of each is used at the commencement, and after three hours rotation the rest. The rotation is continued until free chlorine is present. When the charge is in, a rubber is placed over the man-hole, and an iron plate over this, which is screwed down tight with a long lever as quickly as possible to prevent the escape of any chlorine from the barrel. The barrel is revolved at the rate of 12 revolutions a minute for four hours. At first the whole charge of chemicals was made at one time. This was found not to work advantageously and now the charge is divided. Two charges are always made in a day. In North Carolina half the quantity required to generate the chlorine is introduced at first, and the rest at the end of half the time of rotation, and the process continued. The time of the rotation of the barrel is from 4 to 8 hours, depending on circumstances. When an examination shows free chlorine present the operation is finished. It will not do to trust to pressure alone to determine the presence of chlorine in excess, for other gases are given off as well as chlorine, which would give a false indication if the operation was determined as finished by the pressure alone. A lead valve is arranged in the barrel, so that not only the pressure of an excess of chlorine gas, but its presence and the exact condition of the charge, can be ascertained at any time. Where examination shows that there is an excess of free chlorine in the barrel the pulp should be left in contact with it at least an hour before discharging.

The barrel is surrounded for two-thirds of its height on both sides by a splash-box 18 inches wide, which ends in a trough which can be turned on to any one of the tubs. When the charge is finished the barrel is turned up. The chlorinator, wearing a respirator, as there is considerable pressure of gas, loosens the screw of the man-hole, so as to raise the rubber a little and allow the extra chlorine to escape for several minutes. He then removes the valve altogether, and with his hands turns the barrel down into the trough. The whole charge runs on to the filter, the bed of which is 6 inches in thickness. The filter is first flooded from below to the depth of 4 or 5 inches with water and the outlet stopped. This prevents the charge from below from packing as the ore falls on to it. The barrel is then washed out with a little water, and it is ready for a new charge. The trunnions of this barrel, which was originally made for the Mears process, were made hollow for the purpose of introducing the stationary goose-neck, through

which the pressure of the gas in that process, which was from 30 to 40 pounds to the square inch, was made and measured. They were made too large in the first place, and are now very much too large. They have been stopped up with asbestos, as they are no longer used. In all the recently constructed barrels the trunnions have been cast solid. The difficulty with the barrel so constructed was the leakage of the stuffing boxes for the goose-neck, which it was impossible to keep tight. Another and a greater one was the collapsing of the lead lining of the barrel from the exhaust, in the endeavor to collect all of the chlorine gas in the barrel which was not used in the chlorination, so as to use the gas in the next operation. Another was the fact that there was often pressure due to the evolution of other gases than chlorine, which were mistaken for it, and the fact that, from mistakes as to the pressure, the ore supposed to have been fully acted upon by the chlorine had often not been sufficiently treated, so that the tails had to be worked over. The barrel is run by a 30-inch Knight's wheel.

The time necessary to revolve the barrel is not quite fixed, except by the work of the furnace. The total cost of power is $1 in twenty-four hours, or $0.50 per ton. As the furnace is small the quantity to be treated is small. Double the quantity might be treated if there was sufficient pyrites to treat. Two hours with the Bunker Hill concentrates would answer for the chlorination as well as four. The barrel discharges into three filter-tanks, which are rectangular, 6 feet by 8, and 18 inches deep. They are lined with lead, and incline 1 inch toward the drain-hole. The filter in California is made in them as usual, of quartz pebbles, gravel and fine sand. To keep it in place and prevent its surface from becoming uneven, longitudinal slats 1½ inches deep and 10 inches apart, are used on the top. In North Carolina the bottom of the tank is first covered with perforated tiles which are covered with gravel and then sand. They have two outlets for discharging into the settling-tanks. When the barrel is entirely empty the stopper in the tank is removed and the charge is allowed to drain, and is then washed with clear water, as rapidly as possible, until no gold is left. To do this the barrel-charge is allowed to drain until the surface of the pulp is bare. The outlet is then closed and water is added until it stands 3 to 4 inches above the surface of the pulp; this is then drained. The outlet is again closed and the

vat filled full of water, which will be from 9 to 10 inches deep. This is drained and the tails will then generally be clean. They must, however, be examined and the leaching continued if gold is present. The filtration is done very rapidly, but the time depends for the most part on the fineness of the ore. When the wash water contains chlorine but no gold, the tails will be clean. From 250 to 300 gallons of wash water are required per ton of ore treated. In six hours from the time the roasted pyrites is charged in the barrel the tails are clean and the filter ready for a new supply of barrel-treated ore.

The settling-tanks are round, and are called stock-tanks. There are three of these 8 feet in diameter and 4 feet deep. They settle in fourteen to sixteen hours, and are drawn into the precipitation-tanks, which are on a level below the bottom of the stock-tanks. The precipitation-tanks are 5 feet in diameter and 3 feet deep. In North Carolina they are 6 to 8 feet in diameter, and the same depth. They are quite large enough to hold all the wash liquors of 3 tons of roasted ore. There are six of them. The ferrous sulphate is siphoned into them. The solution must have a decidedly acid reaction, in order to be certain that all the lime has been converted into sulphate. Ferrous sulphate gives a bulky precipitate with neutral solutions of calcium chloride. The solution is stirred with a wooden paddle and the ferrous sulphate added in excess. When the gold is all down the ferrous sulphate is turned off, and the whole allowed to settle from forty-eight to seventy-two hours. The supernatant liquor is allowed to run out and a fresh charge introduced into the vat. The spent liquor is allowed to flow on to a sand filter covered with sacking. The sand is taken up once a year and chlorinated by itself. When copper is present in the ore the weak solution, after the precipitation of the gold, is run over old iron, and then goes to waste. The sulphurets treated assay $55. The tails assay from $3 to $3.50. Occasionally they go as low as $1. The gold is collected carefully, washed to remove the iron salts, and melted as usual. When carefully done the bullion is from 990 to 995 fine. Sometimes it may go as low as 975.

It is a matter of surprise, considering the time and pressure of gas used, that this process does not bring the tails down as low as in the Mears process, where the roasted concentrates were moistened with only 15 to 20 gallons of water, whose only object

was to prevent the roasted concentrates from dusting. The difficulty seems to be in the roasting. No salt was added in the Mears process, and the temperature of the roasting was much higher at the end. The explanation must be found in the roasting, as the wet gas does not explain the difficulty. No time, quantity of lime, or other change seems to affect the tails. The tails, when treated, are thrown into a trough in front of the tanks and sluiced out. Only one cord of wood a day is used in roasting. The experience in these works has been that the tanks last best when the wood has been soaked in linseed oil, dried, and painted with tar or three good coats of white lead. The roasted sulphurets are worked up to 92 per cent. of their assay value. When, as they sometimes do, they contain twice their ordinary value, they are worked just as close, the tails in both cases never containing more than $3.50. When they were worked by Plattner's process in the usual way the tails often contained as high as $7 a ton. The cost of this process, at Bunker Hill, per ton of roasted pyrites is given below:

ROASTING.

Two roasters, at $3.25,	$3.25	
Five-eighths cord of wood, at $6,	3.75	
	——	$7.00

CHLORINATING.

One chlorinator, at $3,	1.50	
Thirty pounds of bleaching powder, at 4 cents,	1.20	
Thirty-six pounds of 66 sulphuric acid, at 3½ cents,	1.26	
Twenty pounds of salt, at ¾ cent,	.15	
Water-power,	.50	
General expenses and loss,	3.00	
	——	7.61
Total for one ton of ore roasted and chlorinated,		$14.61

The cost of doing this in North Carolina is very much less:

ROASTING.

Four laborers for roasting 2 tons of ore, at $1,	$2.00	
One cord of wood for roasting 2 tons of ore, at $1.25,	.625	
	———	$2.625

Chlorinating.

Two laborers for 4 tons, at $0.90,	$0.45	
One chlorinator, at $2,	0.50	
Forty pounds of bleaching powder, at 3 cents,	0.30	
Sixty pounds of sulphuric acid, at 2 cents,	0.30	
Seventy-five pounds of sulphuric acid for ferrous sulphate, at 2 cents,	0.125	
Repairs, wear and tear,	0.20	
Power,	0.125	
	2.00	
Total for one ton of ore roasted and chlorinated,		$4.625

The success of this process is undoubtedly owing to the formation of nascent chlorine in contact with ore, which is constantly being rubbed bright by the friction of the particles against each other and against the sides in the revolving barrel. In two years use of the process at the Haile mine, there have been no repairs. Under the conditions of the process it would be impossible for any coating forming on the particles of gold to remain on them, and if the gold is bright it is sure to be attacked, which might not be the case when the ore is treated in vats. The solution and filtration are done so rapidly that there is little chance for the gold dissolved, to be precipitated elsewhere than in the precipitation tanks. The advantages of this process are the small amount of space it occupies, the celerity of the operation, the high percentage of yield, the facility of ascertaining the exact condition of the charge at any time, and the very slight wear and tear. The only disadvantages are that a small amount of power is required to be used, which is not necessary in the ordinary Plattner's process, and that more than ordinary care and intelligence are required to run it.